Report from the Noble Liquids Group:

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Brief Introduction

- Dark Matter Detection, 0v2β, Neutrino Detectors

• "Conventional" DM Detectors	T. Shutt
• Light Noble Detectors	D. McKinsey
• Directional Detectors	M. Leyton
• LAr TPC	A. Rubbia
• LAr Test Facilities at FNAL & CERN	J. Raaf
• 0v2β with gas Xe, exotic 0v2β	D. Nygren
• LAr R&D Program at BNL	Y. Li
• 0v2β with liquid Xe	G. Gratta
• 0v2β inXe with Ba tagging	W. Fairbank

Findings

- LXe/LAr Dark Matter Detectors (Shutt)
  - Single or Two Phase Detectors, Ar or Xe
  - Scalable to O(10-100) tonnes
  - Two phase detectors use charge/scintillation for NR/ER discrimination
  - Single phase detectors rely on Pulse Shape Discrimination in Ar
  - High discrimination ~99.9 desirable for 30-50 tonne for LCT
  - HV continues to be a challenge
  - PTFE is “unreasonably reflective” in LXe
  - Scintillation light in Lar needs WLS.
  - ^{39}Ar background requires O(10^8) reduction
  - PSD >108 at thresholds 40-50 keV
  - Advent of low background PMTs has enabled current experiments

Findings

- Light Nobles (McKinsey)
  - He4 kinematic matching pulls up energy deposition for low mass DM, in window of masses between few hundred MeV - few GeV
  - Measurement of multiple signals - singlet, triplet scintillation, ionization, and heat could improve ER discrimination
  - LXe detectors doped with Ne could enhance sensitivity to low mass WIMPs
- Directional DM (Leyton)
  - Track shape and head/tail imaged in gas at low pressure ~O(50 Torr)
  - WIMPs have preferred direction in galactic coordinates.
  - CYGNUS is confederation of the DDM community, mostly gas TPC's, emulsion. Some NITPC's. All small.

Findings

- LAR TPC (Rubbia)
  - Large international effort on a number of large scale prototype LAr TPCs.
  - Existing prototypes demonstrate bubble chamber-like tracks.
  - Plan to build 4 x 10 kT LAr modules at SURF. Membrane cryostats, long drift lengths.

- LAr Test Facilities (Raaf)
  - Extensive set of complementary test facilities exist at CERN and FNAL

Findings

- NEXT (high pressure Xe gas) (Nygren)
  - Excellent energy resolution, maybe $<5x10^{-3}$ FWHM at 2457 KeV
  - Topology of events should be clear, with several cm tracks and ionization “meatballs” from stopping electrons. This provides additional discrimination of backgrounds.
  - Non-cryogenic, gas with density <0.55 g/cm^3

Findings

- LAr R&D at BNL (Li)
  - Studies of fundamental properties of LAr, complementary to work at FNAL
- 0v2β (Gratta, Fairbank)
  - EXO-200 discovered 2v2β in ^{136}Xe.
  - Competitive limits on 0v2β in ^{136}Xe.
  - nEXO is foreseen at 5 tonnes, which would be many ɣ interaction lengths, single drift space, SiPM photodetectors, and tile charge collection system.
  - Ba tagging would eliminate all backgrounds save 2v2β, but extremely non-trivial!

Comments

- Dark Matter Detectors
  - Enhanced light collection would enhance the reach of both detectors.
  - Directional detectors might ally with non-directional.
  - Directional to confirm detection likely 100 times larger in mass. Using directionality to push past neutrino floor would require kton or substantially larger mass
  - Underground Ar 1000-fold reduced in ^{39}Ar has been demonstrated, which should allow ~100 ton scale TPCs without strong pileup
- LAr TPC's
  - LAr TPCs are the necessary technology for DUNE, comprising LBNF, nucleon decay, and supernova neutrino detection.
  - Large scale LAr TPC's may be a new instrument for discovery.
  - First module will be single phase; two phase detectors under development.
  - Magnetized modules would be desirable, but may not be practical.

Comments

- 0v2β
  - High Xe purity is required for energy resolution
  - Tracking required for background rejection.
  - EXO-200 backgrounds are accurately modeled
  - nEXO HV may be difficult.
  - Ba tagging R&D in next 3 years is critical for an optimal low background nEXO.
- NEXT
  - Interesting idea for identifying Ba++ using single molecule fluorescence. Needs lots of work.

Identification of Risks and Opportunities

- Risks
  - Lack of sufficiently stable agency support
  - HV management for large liquid detectors
  - Inability to achieve sufficiently low backgrounds for DM, ßß decay
  - DUNE: Long drift requires ultra-high purity

- Opportunities
  - Increased science reach through improved light sensitivity and/or development of ultra-low background light readout.

Recommendations

- Increase funding(!)
- Areas that may need more support:
  - HV management in large detectors
  - Scintillation light detectors: DUNE, DM, nEXO (any synergies?)
  - Noble liquid purification in liquid state

Possible Grand Challenge Ideas

- Feasible high mass directional DM detector.
- Ba tagging in ^{136}Xe 0v2β
- Ultra-low background, high QE (>40%), low dark rate, large area photosensor.